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## ABSTRACT

This report describes features of the Audio Laboratory System (ALS), a device which supports research activities of the Southwest Regional Laboratory's Music Program. The ALS is used primarily to generate recorded audio tapes for psychomusicology research related to children's perception and learning of music concepts such as pitch, loudness, timbre, time, and form. Major sections of the document describe ALS's design, audio components, system components, audio modification, audio recording, monitoring events, and controlling events. Also presented is an inventory which details each module in the ALS control system by programming function. The inventory includes conversion modules, logic modules, timing modules, and counting modules. The report suggests that a major advantage of ALS for psychomusicological research is that it provides for controlled manipulation of the basic vibrational properties of sound. (DB)

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## SWRL EDUCATIONAL RESEARCH AND DEVELOPMENT

### TECHNICAL REPORT 51

MARCH 1974

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THE SWRL AUDIO LABORATORY SYSTEM (ALS): AN INTEGRATED CONFIGURATION FOR PSYCHOMUSICOLOGY RESEARCH

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THE SWRL AUDIO LABORATORY SYSTEM (ALS): AN INTEGRATED CONFIGURATION  
FOR PSYCHOMUSICOLOGY RESEARCH

David Brian Williams and Richard K. Hoskin

The Audio Laboratory System (ALS) is an integrated system configuration that supports research activities of the SWRL Music Program. ALS operates in conjunction with the SWRL Instructional Development Control and Monitoring System (IDCMS) to provide for controlled manipulation of the basic vibrational properties of sound: frequency, amplitude, time, and wave form. ALS is used primarily to generate recorded audio tapes for psychomusicology research related to childrens' perception and learning of pitch, loudness, timbre, time, and form--the fundamental concepts of music.

This report documents the design configuration and capabilities of ALS. Further, the report describes the basic manipulable functions of ALS. The comprehensive and flexible design of ALS, and the potential of its hardware combine to produce a wide array of auditory phenomena, and provide a documented exemplar for the development of any laboratory for psychomusicology research. Both ALS and IDCMS are currently operational at SWRL and constitute a powerful resource that may be of interest to researchers conducting programmatic R&D in psychomusicology.

ALS DESIGN

The audio components of ALS can be classified into three categories: (1) generation, (2) modification, and (3) recording components (Fig. 1).

Verbal or non-verbal auditory patterns can be generated by playback of previously recorded events, live performance, or by one of several signal generating sources. Available signal sources are a noise generator, two sine-square wave generators, a music synthesizer with keyboard access, and a Programable Pitch Generator (PPG) which provides ALS with complete, automated control of pitch generation.

Generated auditory events can be modified by sound amplification, attenuation, filtering, and mixing. A patchboard network provides the necessary switching capability between the audio generation, modification, and recording components.

Auditory events are output for recording onto one of two reel-to-reel, 2-track tape recorders. Audio tapes prepared in the laboratory are designed to be used on IDCMS (Follettie & Teplitzky, 1973).

Track I on the tape is reserved for the recording of stimulus information which is to be heard by the child. Track II is reserved for the recording of "logic tones" which trigger the visual coding device on the IDCMS Master Loading Console. These logic tones are inaudible to the child. Hardware and software modifications have been made on IDCMS to permit programmed coding of IDCMS visual codes directly from recorded logic tones. There is a distinct advantage to this feature. The manual coding of visuals on IDCMS can be eliminated when rigorous control of timing is necessary in an experimental study.

Programable control of the audio generation, modification, and recording units of ALS is provided by a modular installation of

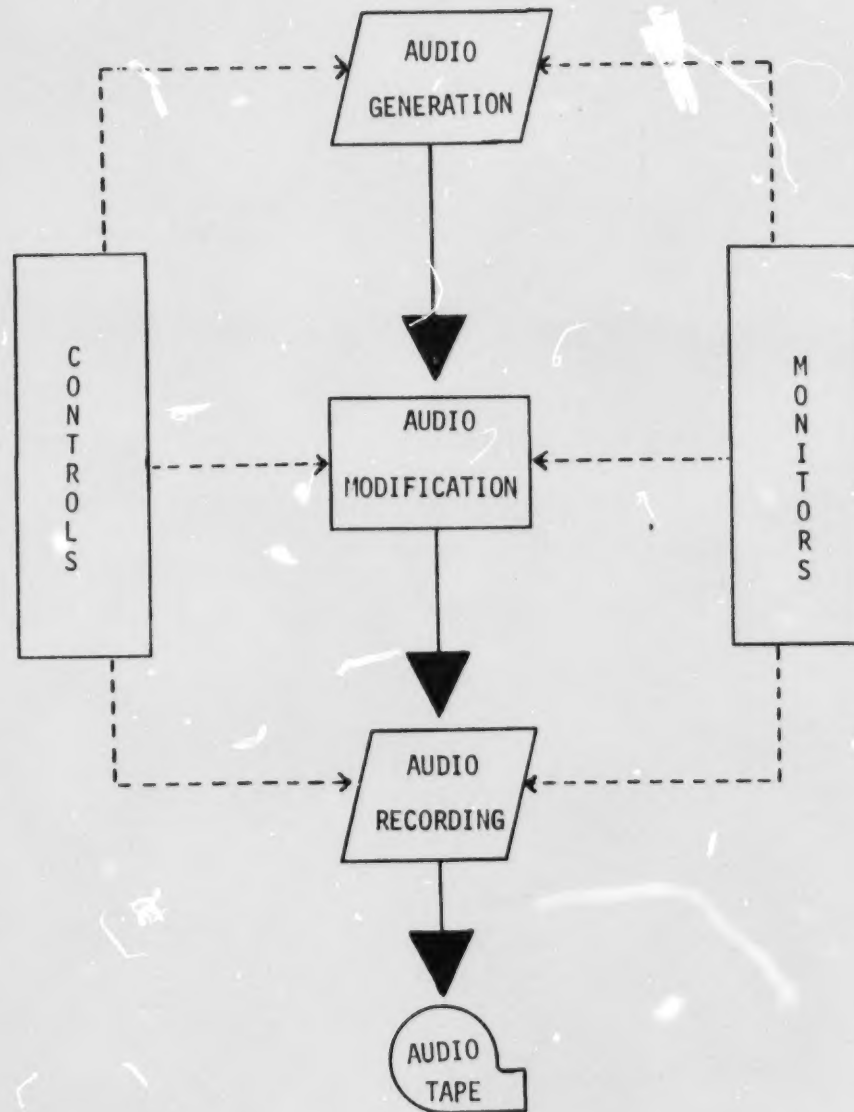


Figure 1: SWRL Audio Laboratory System (ALS).

Grason-Stadler (G-S) Series 1200 precision conversion, timing, counting, and logic devices. The ALS programing system permits auditory events to be converted, stored, counted, timed and otherwise manipulated, and subsequently used to control existing, or to generate new auditory events. Control contingencies are programed in recursive patterns by pinjack connectors on the front panels of the program modules. A master program control panel makes available the option of programing complex logic sequences on storable matrix plugboards.

In addition to the programable control and audio components of ALS, display units provide a monitoring system for recording and measuring the occurence and duration of events generated by the system.

In the following section, specifications for each of the ALS components are discussed. An inventory is provided for equipment available within the programable control, monitor, and audio components of the system. (Note: For the inventory, numbers within parentheses indicate the number of units available.)

#### SYSTEM COMPONENTS

##### Audio Generation

###### Inventory:

1. Electro Voice Cardioid Electret Condenser Microphone, Model 1751 (1)
2. Metronome with remote control (1)
3. Grason-Stadler Noise Generator, Model 1285 (1)
4. E.M.S. SYNTHI Music Synthesizer with DK1 Keyboard (1)
5. Programable Pitch Generator (PPG) with remote control (1)
6. Heathkit Wave Generator, Model EUW-27 (2)

ALS can process either live or electrically produced signal generation. High quality voice or musical instrument performance can be input to ALS via the cardioid condenser microphone. At the present time, a room adjoining the Audio Laboratory is used as a sound attenuated area for live recording.

Primary wave forms are available from the 2 sine-square wave generators. The wave generators produce separate or simultaneous sine-square wave signals. The frequency spectrum for the wave generators is 20Hz to 1mHz, +5%.

The noise generator produces white noise in 3 switch-selected bandwidths: 1kHz, 10kHz, or 100 kHz. White noise can be used for auditory events where masking or signal-detection functions are desired. Additionally, white noise within a 1kHz bandwidth can be used with the ALS programing system to produce random selection of specified experimental events.

The SYNTHI music synthesizer provides a variable--and tuneable--signal generating source. The keyboard can be tuned to an equal-tempered scale. Envelope shape (rise and decay time) and the length of any given tone can be programed on the SYNTHI itself. However, the Programable Pitch Generator (PPG), constructed by the SWRL engineering staff, serves as the main variable pitch source for ALS.

Using the PPG, square or triangle waveforms, or a combination of the two, can be generated over a frequency spectrum of 65.4 to 987.8 Hz (tuned in 4 successive equal-tempered octaves). To program the PPG, single or multiple pitch events (up to 3 vertical tones) are coded on paper tape through a teletype or equivalent paper-punch system. The punched tape is then mounted onto the PPG's reel-to-reel drive system. For a pitch event to sound, the PPG is remotely accessed through the ALS programming system. Approximately 10,000 pitch events can be programmed on a given paper tape. Up to 16 pitch events per second (64th notes when  $\text{ } = 60$ ) can be accessed by remote control. The latency time between access requests is less than 20 msecs.

#### Audio Modification

##### Inventory:

1. Altec-Lansing Programable Bandpass Filter (1)
2. Shure Microphone Mixer (1)
3. Grason-Stadler Attenuator/Mixer, Model 1292 (2)
4. Grason-Stadler Programable Attenuator, Model 1284 (1)
5. Grason-Stadler Electronic Switch, Model 1287B (2)
6. Patchboard Network

The programable bandpass filter permits controlled manipulation of the harmonic partials of any waveform. The bandwidth spectrum is in graduated units from 40 to 12.5 kHz. Separate high pass filter (40, 80, and 160 Hz) and low pass filter (16, 12, and 6kHz) switching is also available for waveform modification.

Incoming live sound sources can be mixed through the microphone mixer. Electrically generated sound signals can be mixed through the attenuator-mixers or through the patchboard network. Up to 4 separate signal inputs can be simultaneously mixed. Line impedance loading is the only restriction on signal mixing. Signals combined through the G-S mixers are reduced by -10dB when mixed.

Whenever precise control of voltage level is required, attenuation can be initiated manually or by programing ALS. Manual modification of signal voltage levels is provided by the 2 G-S attenuator-mixers in 1 dB steps from 1 to 30 dB. The programable attenuator is operated by the ALS programing system. The degree of attenuation possible by programing is the sum of the binary-coded dB values (0.5, 1, 2, 4, 8, 16, 32, 64). Thus, from 1 to 127.5 dB attenuation is possible in 0.5 dB steps.

The single-channel electronic switches offer controlled on/off switching of audio signals. There are 9 rise-decay time selections from 10 msec to 250 msec.

A patchboard network using phone connectors provides connection between ALS's 2 tape recorders, bandpass filter, and stereo-speaker amplifiers. Other input-output devices can also be patched into any of these components. A 4-socket patch in series permits multiple connections.

### Audio Recording

#### Inventory:

1. Ampex AC 500 Tape Recorder (1)
2. Revox A77 Tape Recorder (1)

The Ampex machine is a 2-track, reel-to-reel recorder. Up to 2 input sources can be mixed per channel. Operating speeds are 3 3/4 and 7 1/2 i.p.s.

The Revox A77 is also a reel-to-reel, 2-track recorder with the same operation speeds. The Revox machine has two additional features. First, automatic stopping can be programed by splicing in clear leader tape. The stop functions by a photosensing cell installed in the tape head assembly unit. Second, remote advance/stop is provided. Remote control of tape advance and stop is initiated by a G-S programing module (Output control module, Model 1222).

### Monitoring Events

#### Inventory:

1. Heathkit Frequency Counter, Model IB-1100 (1)
2. Modified HSI Digital Clock, Model 42005 (1)
3. RCA Oscilloscope, Model WO-33A
4. Grason-Stadler Cumulative Digital Printer, Model 1238 (1)
5. Grason-Stadler Monitor Lamp, Model 1224 (1 x 8)\*
6. Grason-Stadler Cumulative Counter, Model 1215 (1 x 4)
7. Grason-Stadler Level Meter, Model 1289 (1)

The RCA oscilloscope and the Heathkit frequency counter permits precise visual monitoring of audio signals. The frequency counter will analyze any waveform when a dominant fundamental is present. However,

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\*(1 x 8) is to be interpreted as 1 unit consisting of 8 parts, in this instance, 8 lamps.

due to the time clock integral to its counting system, an audio signal must be of a duration greater than 1 second (for frequencies above 1mHz, 1 msec). Readout is displayed on 5-digit, cold cathode tubes.

Counting of events can be monitored on either the G-S cumulative printer or counters. The cumulative printer provides 3 separate channels for recording events on paper. Input to the printer can be from either nonG-S, or from G-S programing units. Printout occurs on the 3 channels simultaneously when triggered by the ALS programing system. Reset of the counting can be triggered at any time, alone or simultaneously with printout.

The 2 cumulative counters provide display counting of up to 8 separate events. Reset is manual.

Time events can be monitored either by the G-S cumulative printer or the HSI digital clock. The digital clock has been modified to allow remote start/stop from a G-S programing module (Output control module, Model 1222). Reset, however, is manual. If a permanent record of timings is needed (e.g., response latency or tape recording time) the cumulative printer can be utilized with additional programing control required from the ALS programing system. Basically, the procedure entails using pulses from a 40 Hz sine wave--the maximum counting rate of the printer is 40 pulses per second. Control modules from the programing system permit counting at the rate of 40 p.p.s. from onset to offset of the timing interval. Thus,

$$\text{Time} = \text{Total Pulses} \times .025$$

For monitoring of a sequence of events, the G-S monitor lamp module provides 8 lamps for visual display. The level meter gives voltage and decibel-change readout and is useful for monitoring and calibrating audio signals on ALS.

#### Controlling Events

The programable control units of ALS are a modular Grason-Stadler Series 1200 system (Grason-Stadler, 1967). The system is made up of a number of discrete programing modules, each serving a separate and distinct control function. Program communication between modules is formed by interconnective pin jack cords inserted in the front panels. Permanent recording and storage of programs is possible by recreating programs on removable matrix plugboards.

Four types of programing functions are available: (1) conversion, (2) timing, (3) logic, and (4) counting.

Following the flow of control events illustrated in Figure 2, it can be seen that first, an input voltage or relay contact must be provided by an external electrical or mechanical device. External events, for example, could be audio signals or a momentary open or closed electrical circuit.

The programing function of conversion provides the necessary interface between external events and the ALS programable control system. All external signals are converted to a voltage signal which is acceptable to any module within the programing system. After conversion, the resultant voltage is a -10 volt pulse or dc signal which can be represented as program logic, 1. Its complement is a 0 volt signal

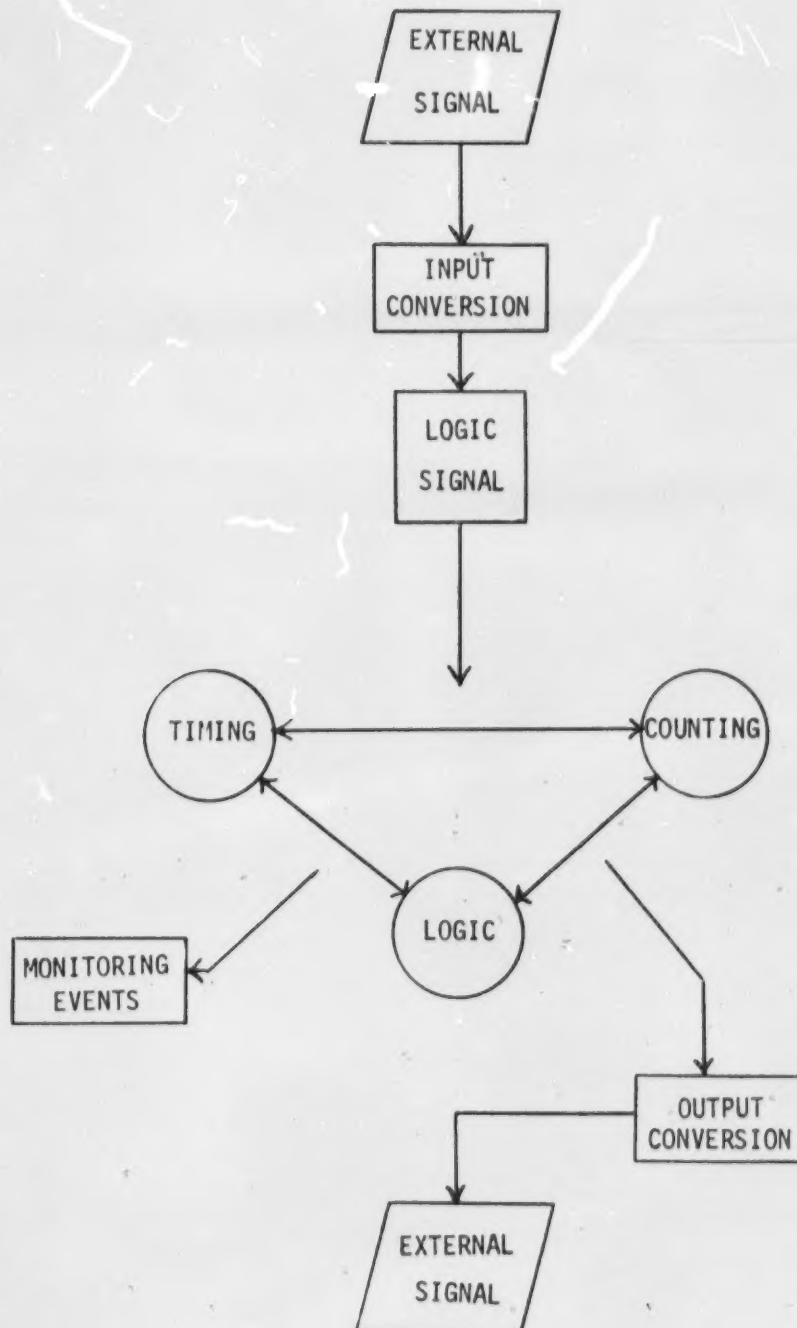


Figure 2: Flow Of Central Events In ALS.

(i.e., absence of a signal) which can be represented as program logic, 0. Each module within the ALS programable system accepts either a 1 or a 0 logic signal, and furthermore, each module emits a 1 or 0 logic signal. Essentially, this is the program language that controls all functions within the system.

The second step in the flow of control events is the utilization of the converted logic signal for effecting sequences of program contingencies formulated to control any external series of events. Timing intervals can be programed, as well as program events contingent upon whether a given time interval is in process or is completed.

Logic or decision branches can be programed. There are 3 basic logic functions: AND functions, i.e., specifying events which coincide in time; OR functions, i.e., specifying all contingent events, whether or not they coincide in time; and NOT functions, i.e., specifying all that is not an event.

Counting of events can be programed. As counting takes place program contingencies can be specified as a discrete event occurs, or at the end of a selected count of events.

As a third step in the flow of control events, the previously detailed monitoring components can be programed to record visually or by permanent record the sequence, counting, or timing of program events.

Finally, at specified points in a program, the logic signals are used to trigger events external to the system. Conversion now results in opening or closing a relay contact to stop or start an electrical or mechanical device. Output control can be used, for example, to turn an audio signal on/off, advance/stop a tape recorder, start/stop a digital clock, or attenuate an audio signal.

The following inventory details each module in the ALS control system by its respective programming function.

Inventory (Grason-Stadler 1200 Series Modules):

A. Conversion modules

1. Input Converter, Model 1211 (3 x 2)
2. Output Control, Model 1222 (3 x 2)
3. Level/Zone Detector, Model 1270 (1 x 2)
4. Electronic Switch, Model 1287B (2)

B. Logic modules

1. AND Gate, Model 1213 (2 x 4)
2. OR Gate, Model 1212 (1 x 4)
3. Composite, with inverter and amplifier, Model 1214 (2 x 2)

C. Timing modules

1. 100-second Timer, Model 1216A (3)
2. 10-second Timer, Model 1223 (3 x 2)

D. Counting modules

1. Preset Counter with Readout, Model 1220 (1)
2. Sequence Counter, Model 1219 (3)

Conversion modules. The input converter module makes a variety of signal sources compatible with the ALS programmable control system by converting the incoming signal to a 1 logic signal acceptable to the programming system. Conversion can be obtained by contact-to-ground (N.O.), interruption of contact-to-ground (N.C.), positive pulses (8-20 volts), and sine waves (10-10,000 Hz). The output control converts the system logic signals into relay contact closures capable of controlling any external electromechanical device. The module circuit is a SPDT contact. Duration of the contact can be set for 10, 30, or 100 msecs, or for the duration of any 1 logic signal applied to the

module. Two of the 3 output control modules are permanently wired for standard ALS controls: one for the Revox tape recorder remote advance/stop, and one for the HSI digital clock remote start/stop.

For interfacing audio events with the ALS programable control system, the level/zone detector module is equipped with 2 level-detection channels. Used independently, a 1 logic signal is generated whenever an incoming audio voltage exceeds the selected threshold. Used in conjunction with one another, a 1 logic signal is generated whenever a voltage is detected within the selected voltage zone. A polarity switch allows the definition of positive- or negative-going audio signals.

The electronic switch, although primarily an audio modification unit, also includes a level detection feature. A 1 logic signal is generated from the switch whenever the incoming (whether or not the switch is open) audio voltage exceeds the selected threshold. Its main purpose, however, is to synchronize the turn-on and/or turn-off of the signal waveform at precise points in time.

Logic modules. An AND gate is used in ALS programs where 2 or more contingencies are to coincide before a given event occurs. Each module contains four 3-input AND gates which accept 1 logic signals from other control modules. When an ALS program requires triggering events whether or not the contingent events coincide in time, an OR gate is used. Each OR module contains four 3-input, inclusive OR gates, i.e., output signals are not inhibited when 2 or more events occur simultaneously.

A composite module has 2 flip-flops, an amplifier, and an inverter. The flip-flop is capable of operating as a memory function or as a

binary counting function. Once set by an input 1 logic signal, it will maintain that signal until a logic signal appears at its reset mode. Several flip-flops in series will record a number of events having taken place in an ALS program. If, however, the reset mode is ganged in series with the set mode of the flip-flop, the unit will alternately change state (1 and 0) with each successive input signal.

When several ALS modules are to be driven from one common source, the output from the common module can be passed through an amplifier. The signal can then be used to drive up to 6 additional modules. In order to obtain the complement or negative of any logic function, logic signals are passed through the inverter. In the absence of an input signal, the inverter produces a 1 logic signal; in the presence of a 1 logic signal at its input, the inverter produces a 0 logic signal.

Timing modules. In total, there are 9 timing units in the ALS programing system. The range of timing intervals possible is from .01 msecs to 100 secs. Timings can be selected from the preset timing increments available on each unit. A 10-second timer has 12 time intervals from .15 to 10 seconds in the repeating sequence .15, .2, .3, .5, .75, 1, etc. (+3%).

A 100-second timer has 19 intervals from .1 to 100 msecs/secs in the repeating series .1, .15, .2, .3, .5, .75, 1, 1.5, 2, etc. (+5%). A range selection switch permits operation in either the seconds or milliseconds mode. An additional feature of the 100-second timer is the variable fine timing control for attaining any time interval between two fixed steps. Furthermore, this timer can function in its normal

operating mode, in a recycle mode--automatic recycling of selected time every 10 msecs, or in an operate-reset mode--time cycling is reset if the second signal is received while the first time cycle is in progress.

Timing modules have 2 complementary output signals for driving other ALS modules. During a time interval, the output modes are 1 and 0 logic signals; after a time interval has expired, the output modes are reversed to 0 and 1. This feature is useful for initiating events during or after timing intervals occur.

Counting modules. A preset counter permits counting incoming ALS program signals from 1 to 99 events. After the selected count has been reached, a 1 logic signal is output to trigger associated modules in the ALS system. The counting criterion can be manually preset, or set remotely by means of 4 binary signal inputs.

A sequence counter can be used independently, or ganged in series with other sequence counters. Used separately, a sequence counter has a counting range of 0-9. There are 3 sequence counters on the ALS system. Connected in series, the count can be extended arithmetically by tens, hence an ALS counting range of 0 to 39. When connection is made in a decade configuration, each counter represents 1 decimal place, hence an ALS counting range of 000 to 999, or 3 decimal places.

Using the reset capability of the sequence counter, a counting range may be defined between any desired programming points. This also includes omissions in the count, e.g., 1 to 25 by odd numbered

events only. The counting cycle can be automatically recycled.

The utility of the sequence counters is their ability to produce output logic signals at any specified point in a counting cycle. Thus, they offer a wide range of control over associated events, for example, selecting a different sound intensity level on each event between 1 and 5. With additional ALS programing this type of selection can be made at random points in the sequence of intensities.

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